Wearable barcode scanning

Advancements in code localization, motion blur compensation, and gesture control

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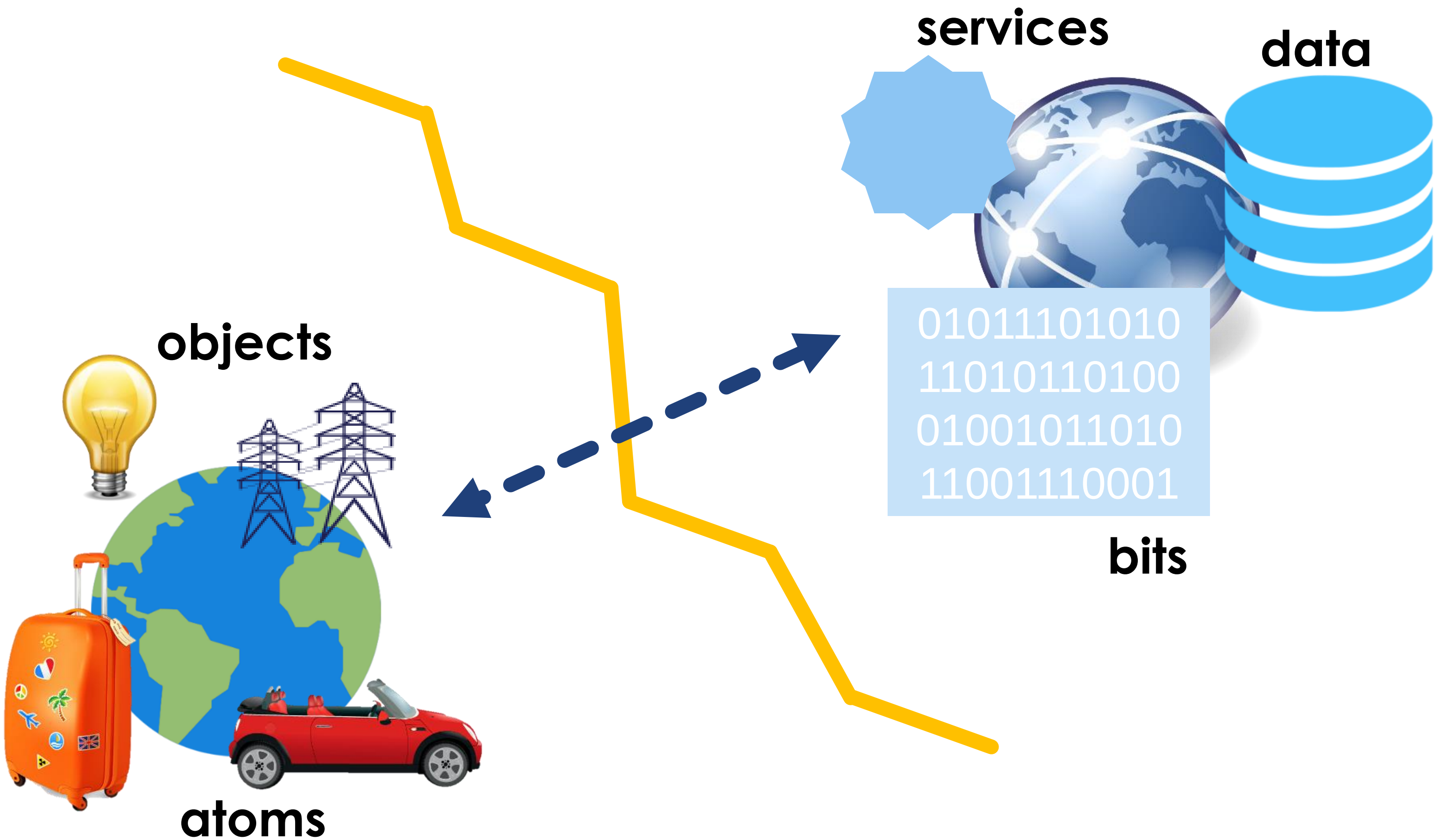
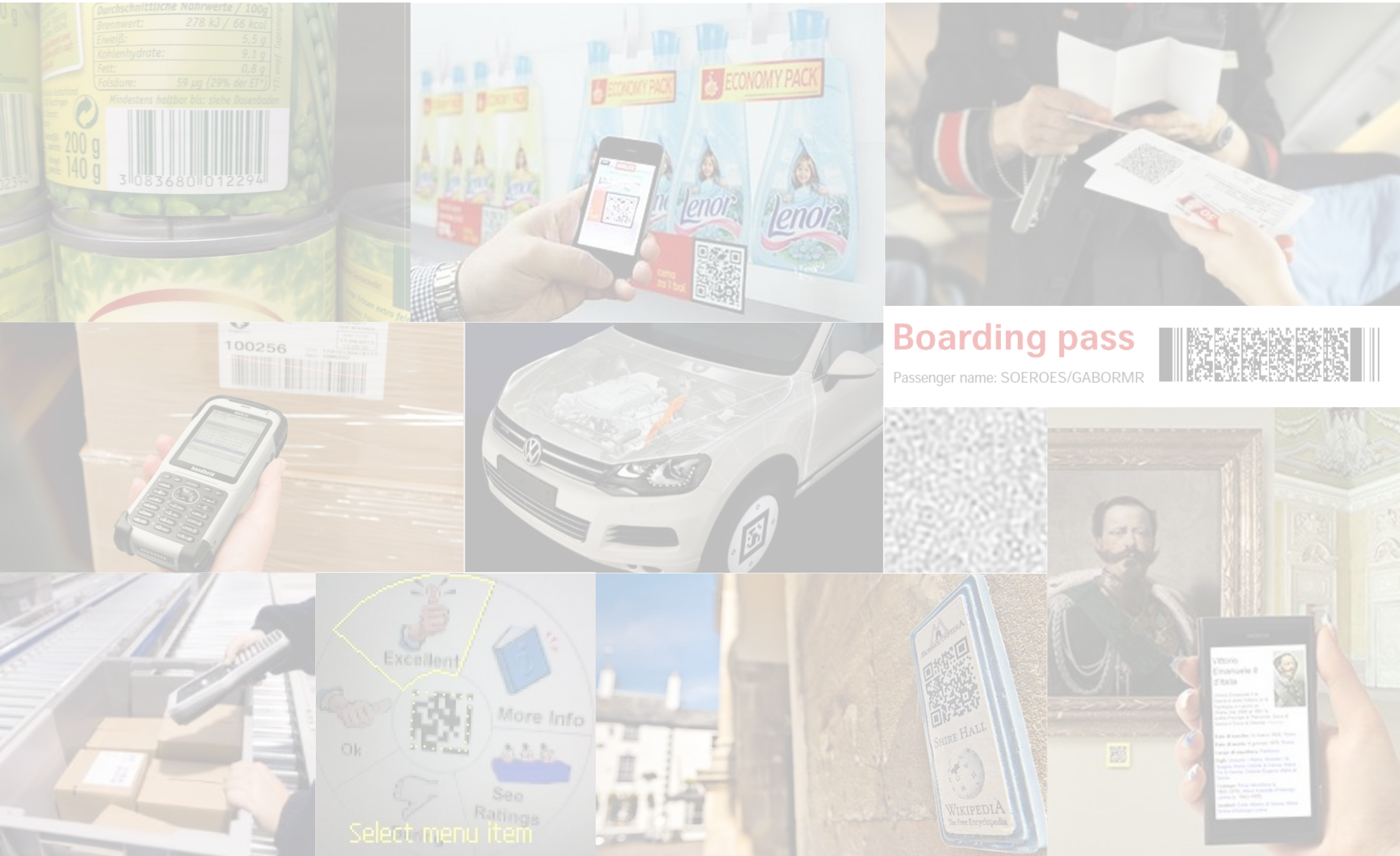
Linking the physical and the digital

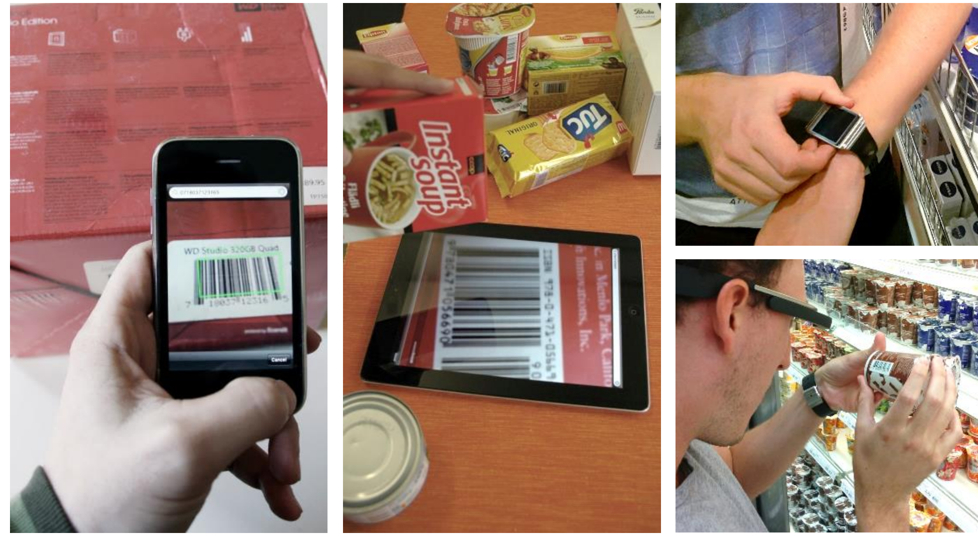


Visual codes are everywhere



Wearable barcode scanning

traditional barcode scanning



wearable barcode scanning

Barcode scanners

- are expensive
- are used by only few people
- use proprietary protocols

Smartphones, tablets, watches, glasses

- are always with us
- have cameras, sensors, intuitive UI
- are easily programmable

Ubiquitous wearable scanners allow us to access information on every physical object

Challenges

no laser for
localization

(multiple)
small codes

defocus and
motion blur

limited input
capabilities

Research goals

- Make **wearable barcode scanning** an attractive alternative of traditional laser scanning
- by compensating the shortcomings, and adding **new features**
- by leveraging the advanced **computing** and **sensing** capabilities of the wearables

Contributions

Fast and robust localization of visual tags

MUM'13, ICASSP'14

Part I

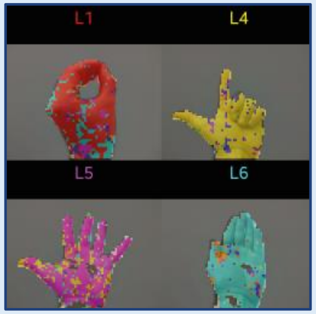
Fast and robust blur compensation for scanners

WSCG'15, ISWC'15

Part II

Fast and robust gesture control for wearables

BSN'14, UIST'14, CHI'15



Part III

Fast and robust code localization

goals: invariant to size, orientation, blur, symbology

Observations

- 1D barcodes contain lots of **edges**

  blur deletes many of them

- 2D barcodes contain lots of **corners**

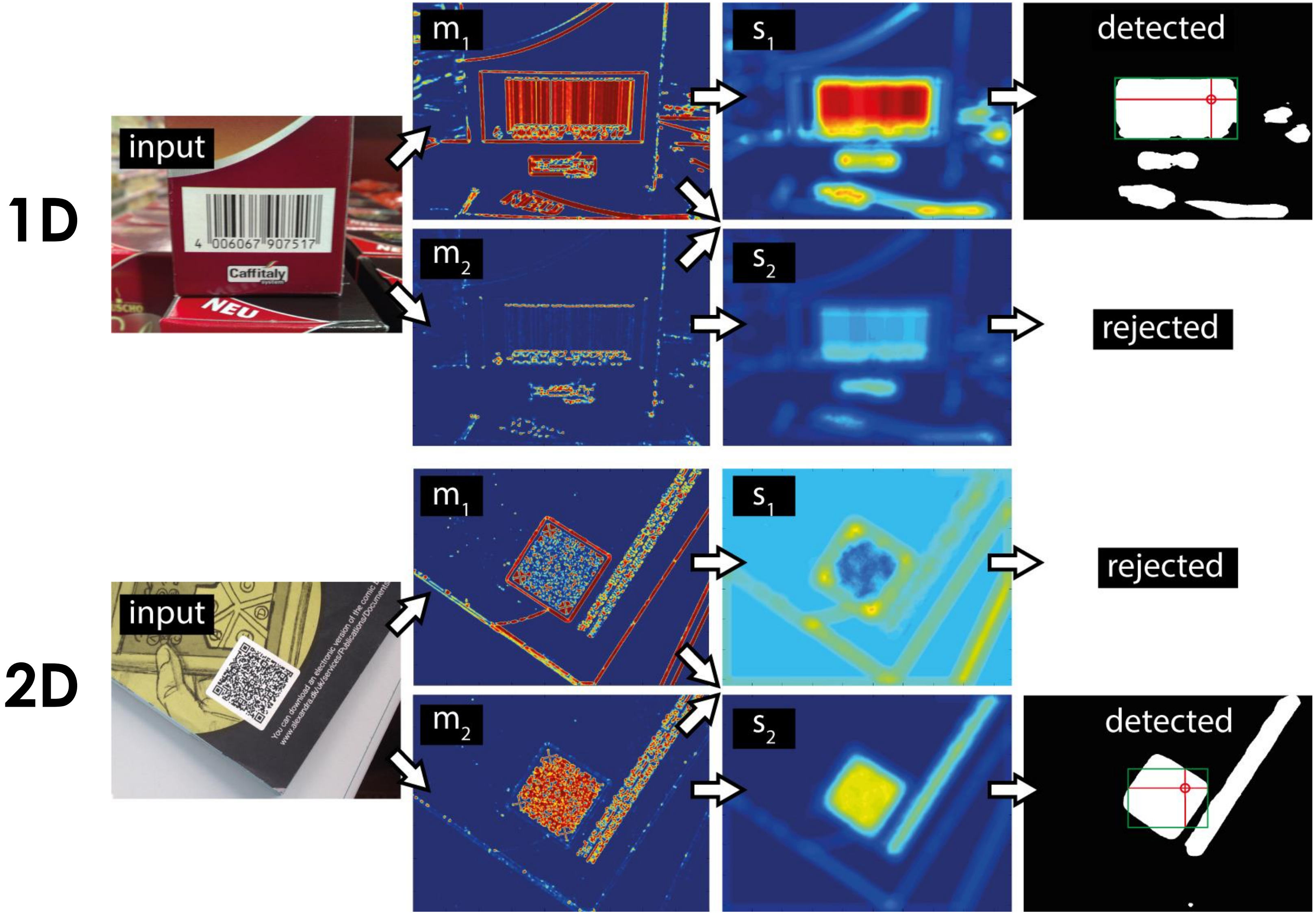
  blur smears corners but they still remain corners

- codes are almost always **black and white**

  blur mixes black and white to gray

➡ **detect areas with edges and/or corners & low saturation in HSV color space**

Joint 1D and 2D barcode localization for smartphones



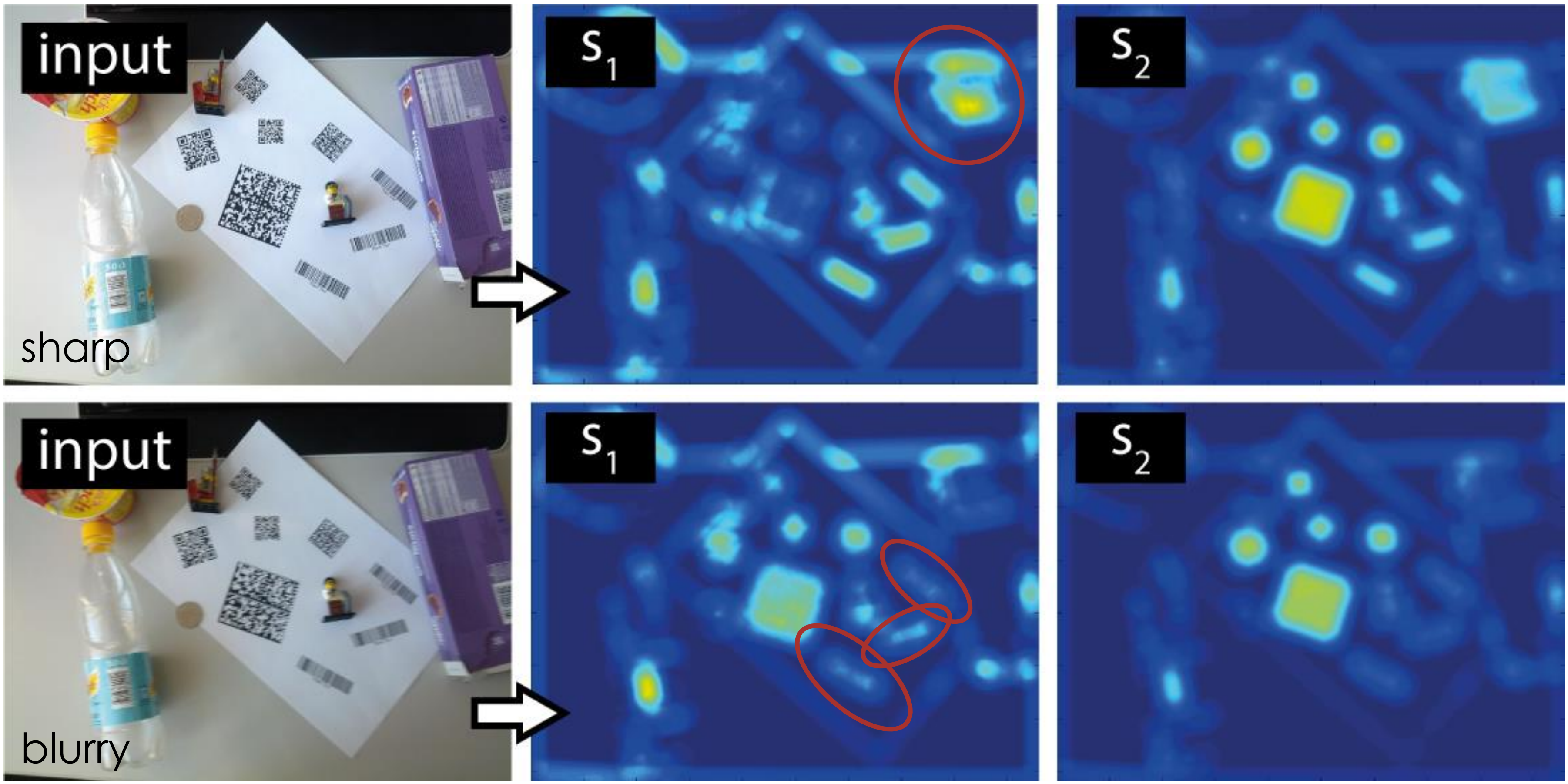
Live localization on the mobile GPU

Results

Our method

- can localize visual codes of various symbologies
- with performance like the state of the art
- without assumptions on code **size**, code **orientation**, or code **position**, while it is more robust to **blur**
- is portable to **GPU** and a wide range of devices

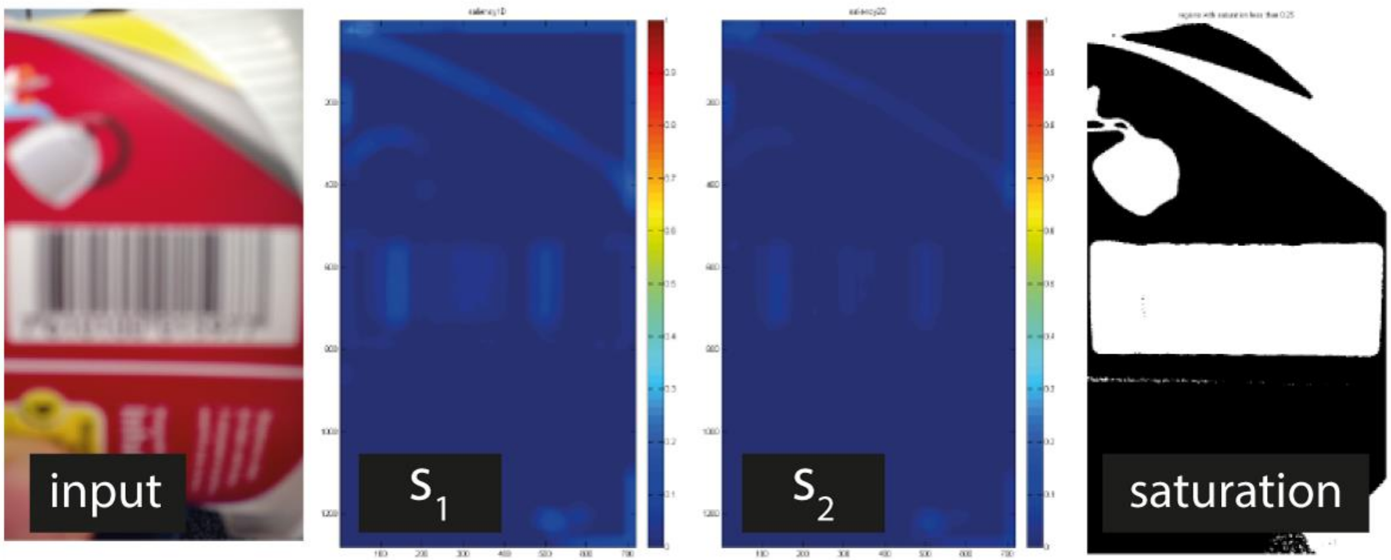
Multiple codes



1D sensitive to blur

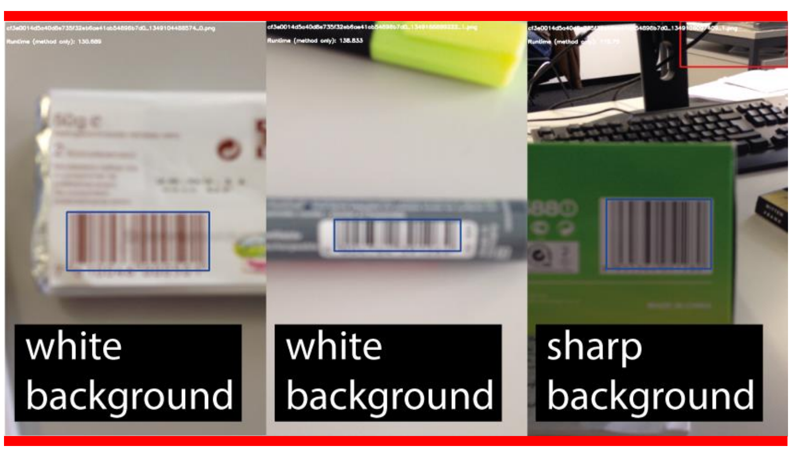
2D works well in both cases

Extension to blurry 1D codes



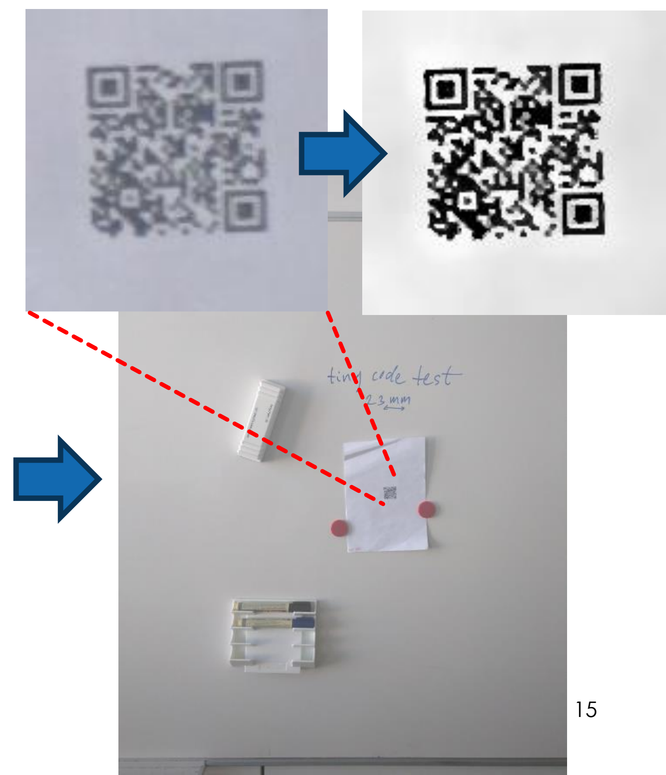
Low S_1 and S_2

Rectangle detection in the saturation channel



Fast and robust code localization allows:

- scanning multiple codes simultaneously
- scanning visual codes from further away
- scanning blurry codes in the whole image



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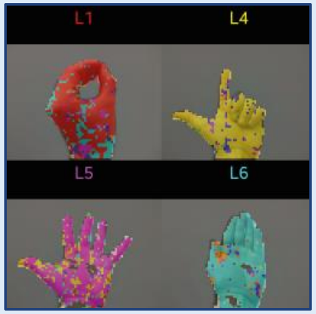
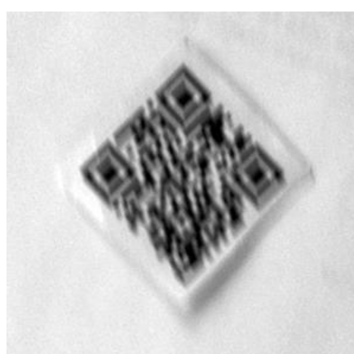


Part III

Motion blur compensation

motion blur makes the codes unreadable

we recover the information from motion-blurred QR codes



our input

our output

Basics of blurry image formation

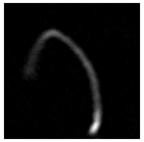
uniform blur model

sharp scene
$\boldsymbol{I}$

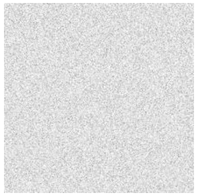
blurry scene
$\boldsymbol{I} * \boldsymbol{k}$

observed image
$\boldsymbol{B} = \boldsymbol{I} * \boldsymbol{k} + \boldsymbol{n}$

convolution with a blur kernel $\boldsymbol{k}$



adding camera noise $\boldsymbol{n}$



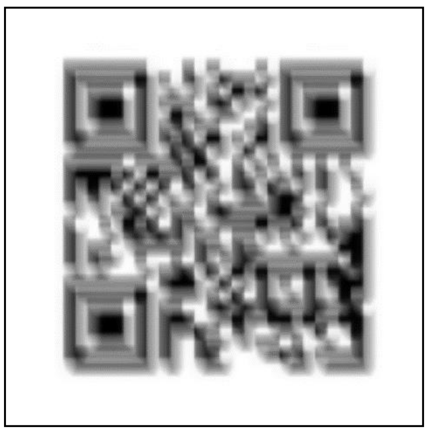
Blur removal problem

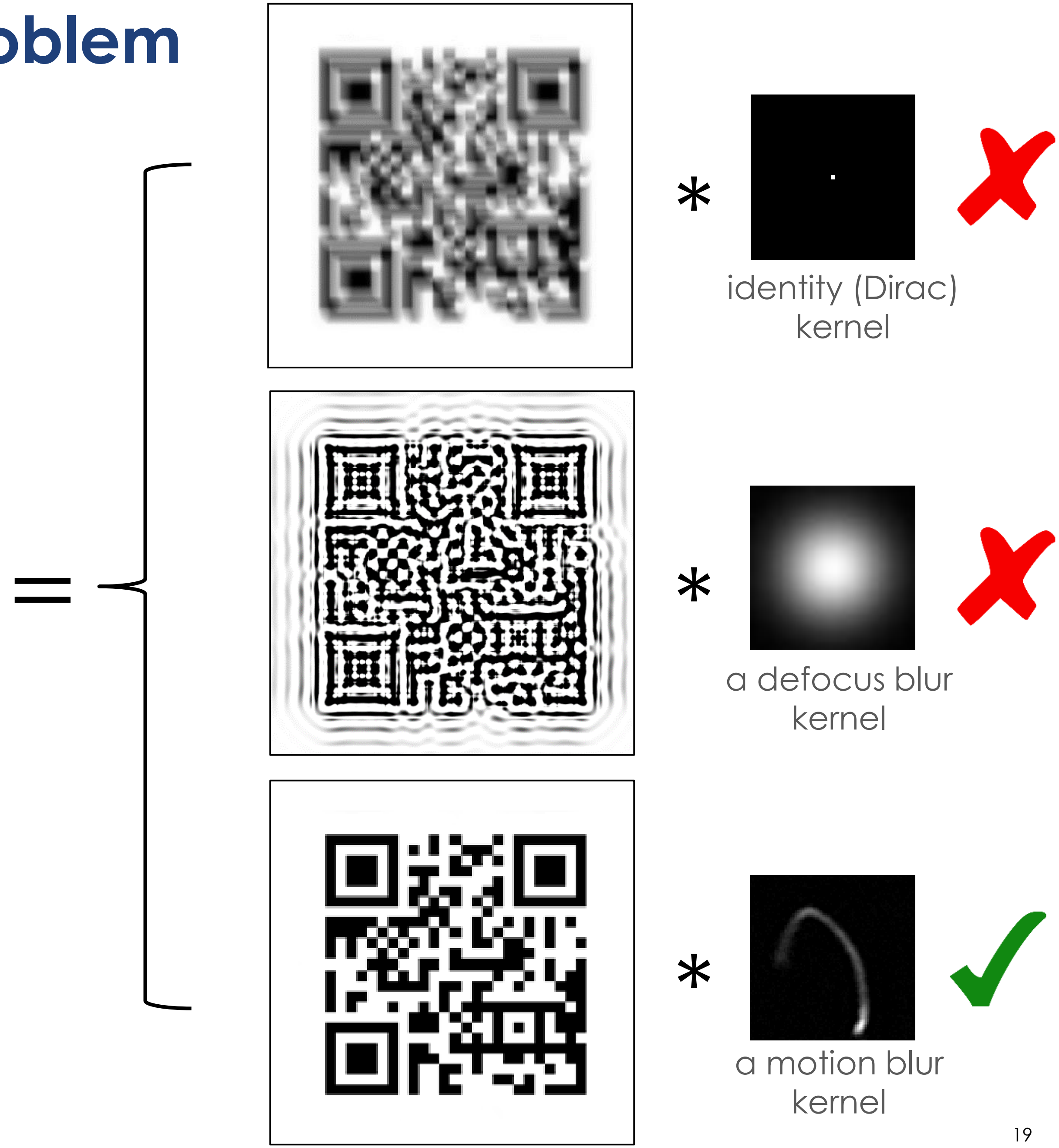
deconvolution:

$$B = ? * k + n$$

blind deconvolution:

$$B = ? * ? + n$$

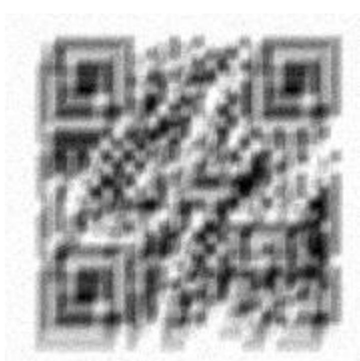




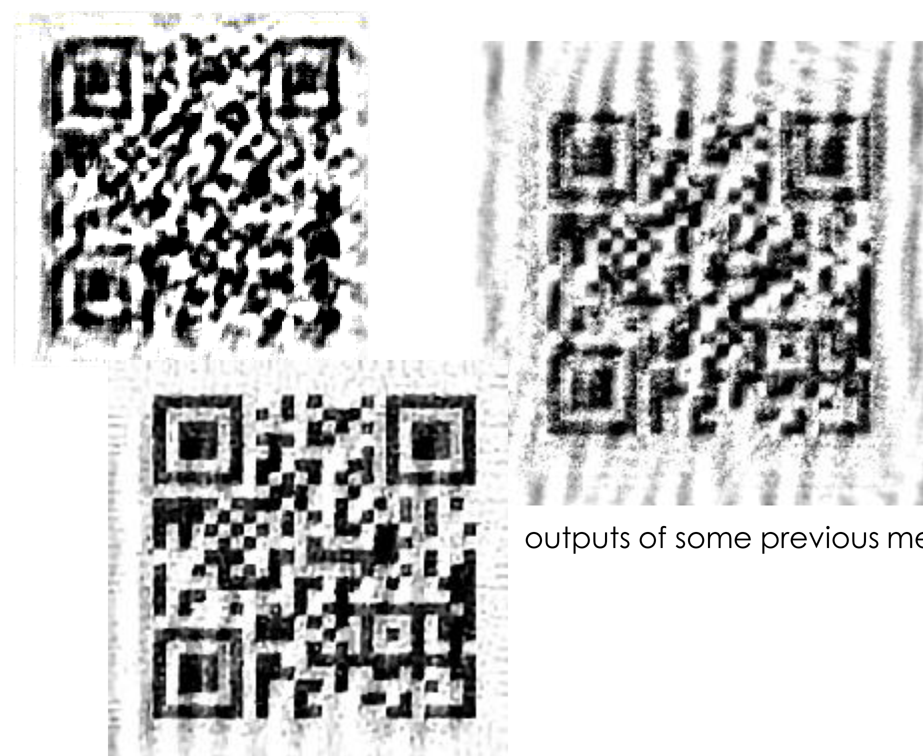
Blind deconvolution for QR scanning?

Existing blind deconvolution algorithms

- are slow even on PC
- are tuned to natural images
- usually fail on QR codes (structure very different!)



input



outputs of some previous methods

Observations for deblurring QR codes

- blur can be estimated from the **many QR edges**
  - but we need to suppress the small structures

- QR codes do not need to **look** good for **decoding**
  - in contrast to photographs, where restoration quality counts, our main concern is speed

- QR codes include **error correction** / **checksum**
  - the algorithm can stop when the checksum is correct
  - false decoding is practically impossible
  - only partially restored codes might be decoded too

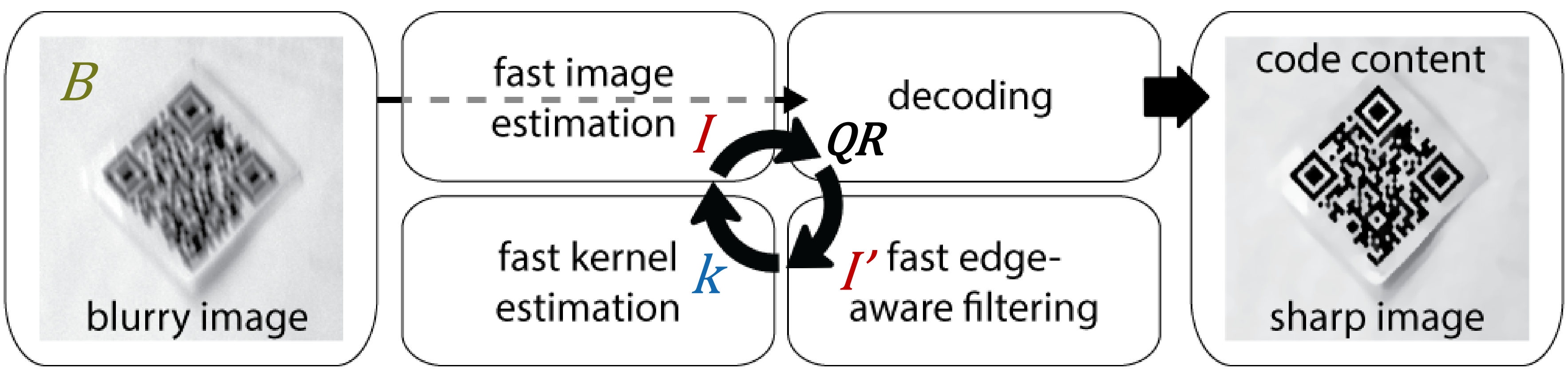
Restoration-recognition loop

Blind deconvolution via energy minimization

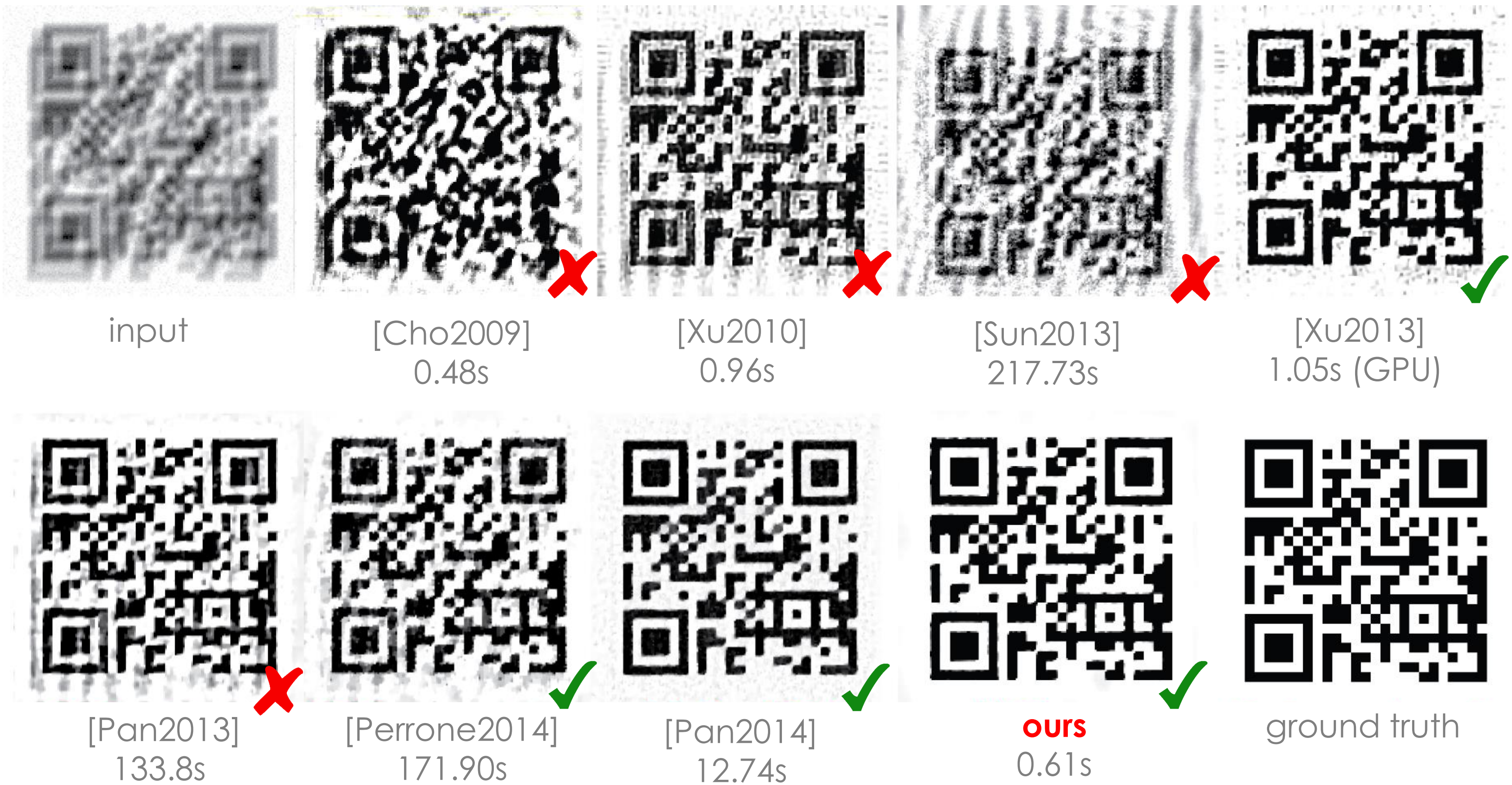
$$\underset{I,k}{\operatorname{argmin}} \|B - k * I\| + \lambda_I p_I(I) + \lambda_k p_k(k)$$

We follow a common recipe for blind deconvolution:

- **alternate** between solving for **I** and solving for **k**
- **suppress noise** and **boost edges**: enforce QR properties
- try to **decode** at every iteration
- repeat on several **scales**

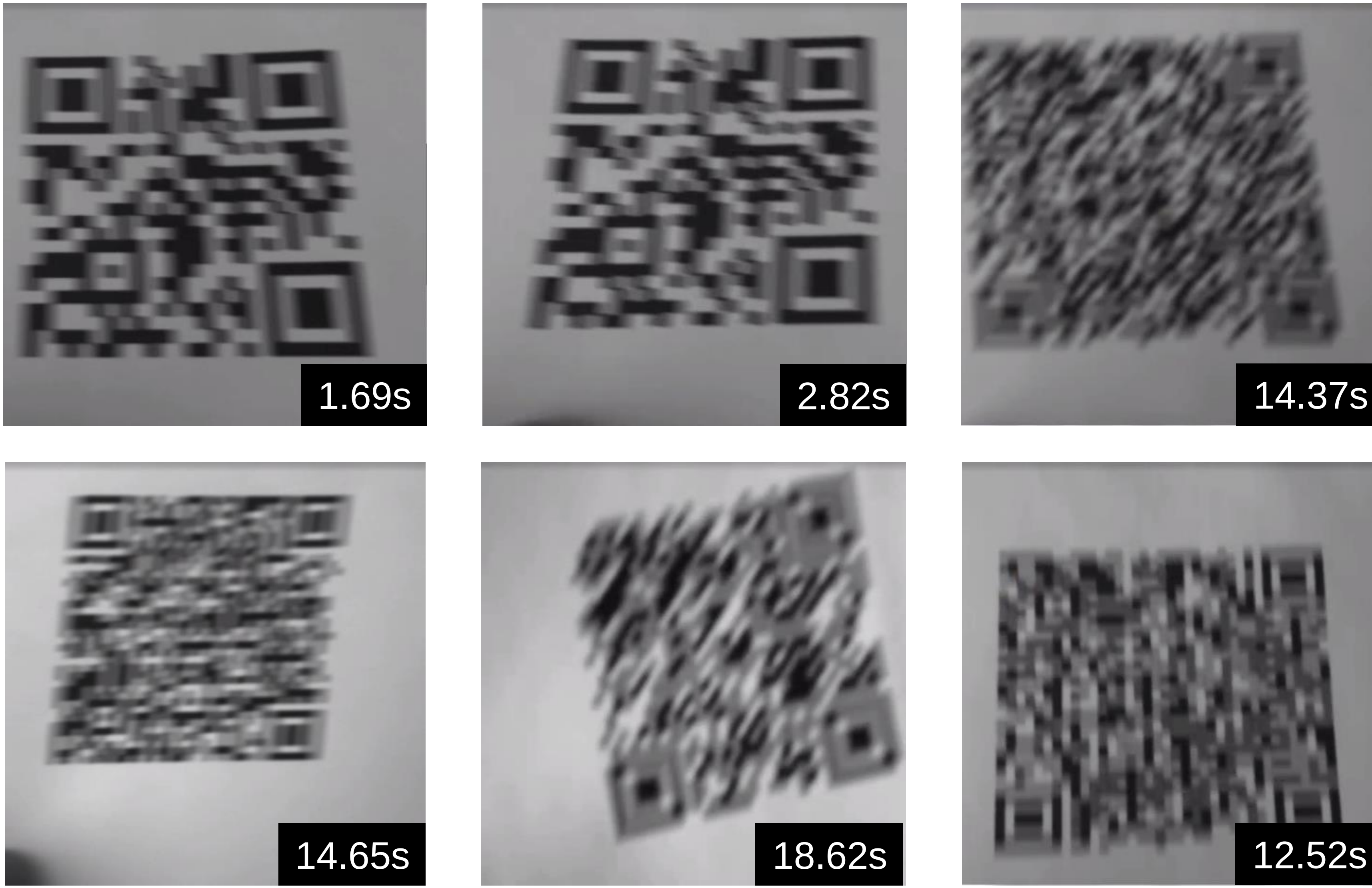


experiments (synthetic blur)

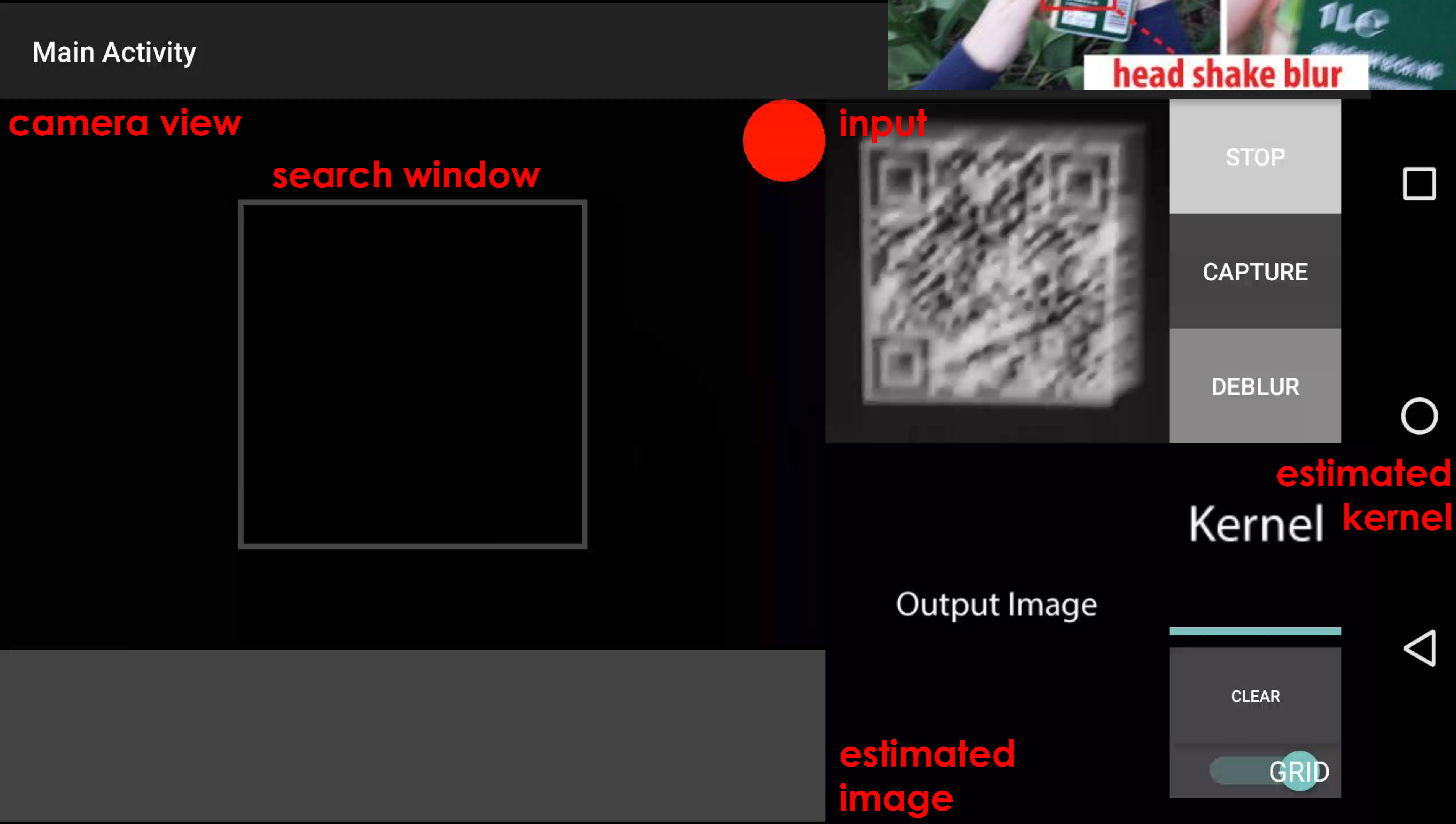


quality is on par with the state of the art, and a magnitude faster

experiments (real blur)



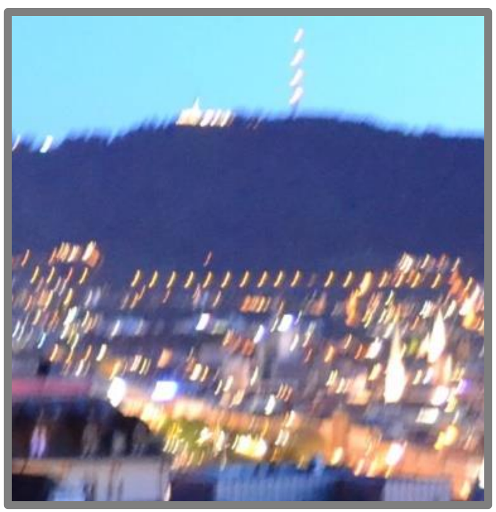
Live deblurring on a smartphone

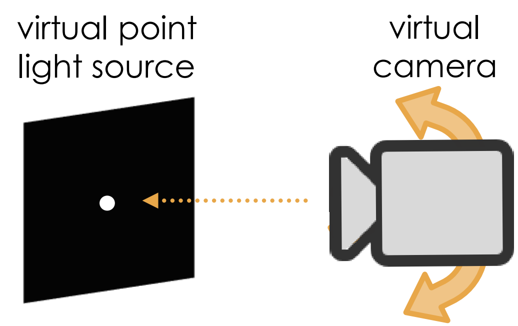


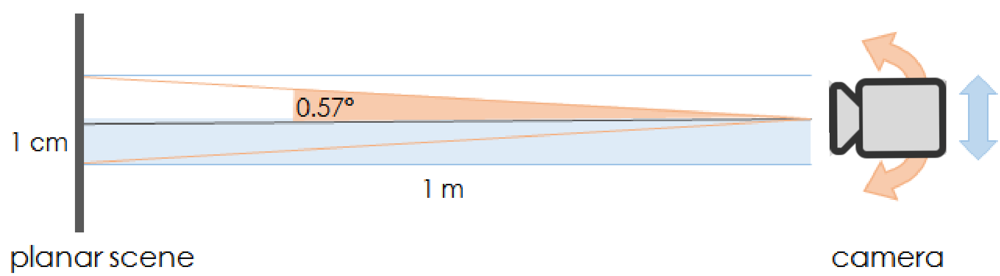
Can we make it even faster?

additional clues:

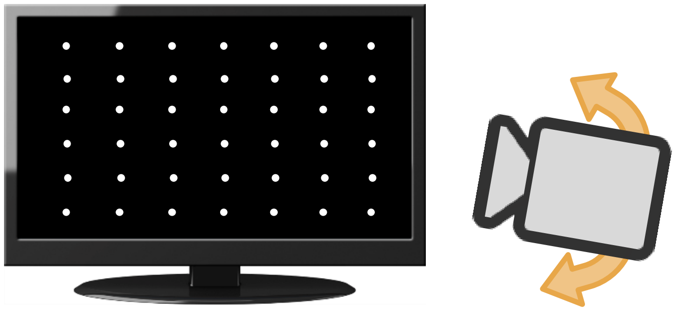
- the blur is ’encoded’ in the image of point light sources
- wearables have inertial sensors
- rotational motion blur is dominant – use gyroscopes
- reconstruct the camera motion, render the blur kernel



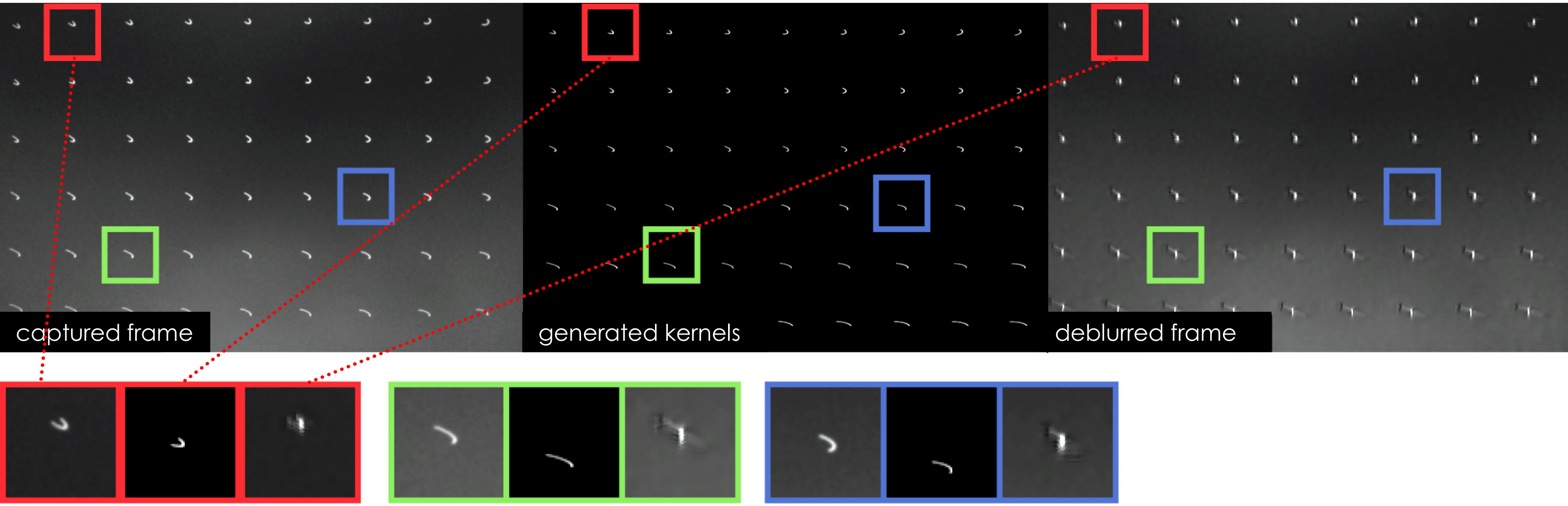




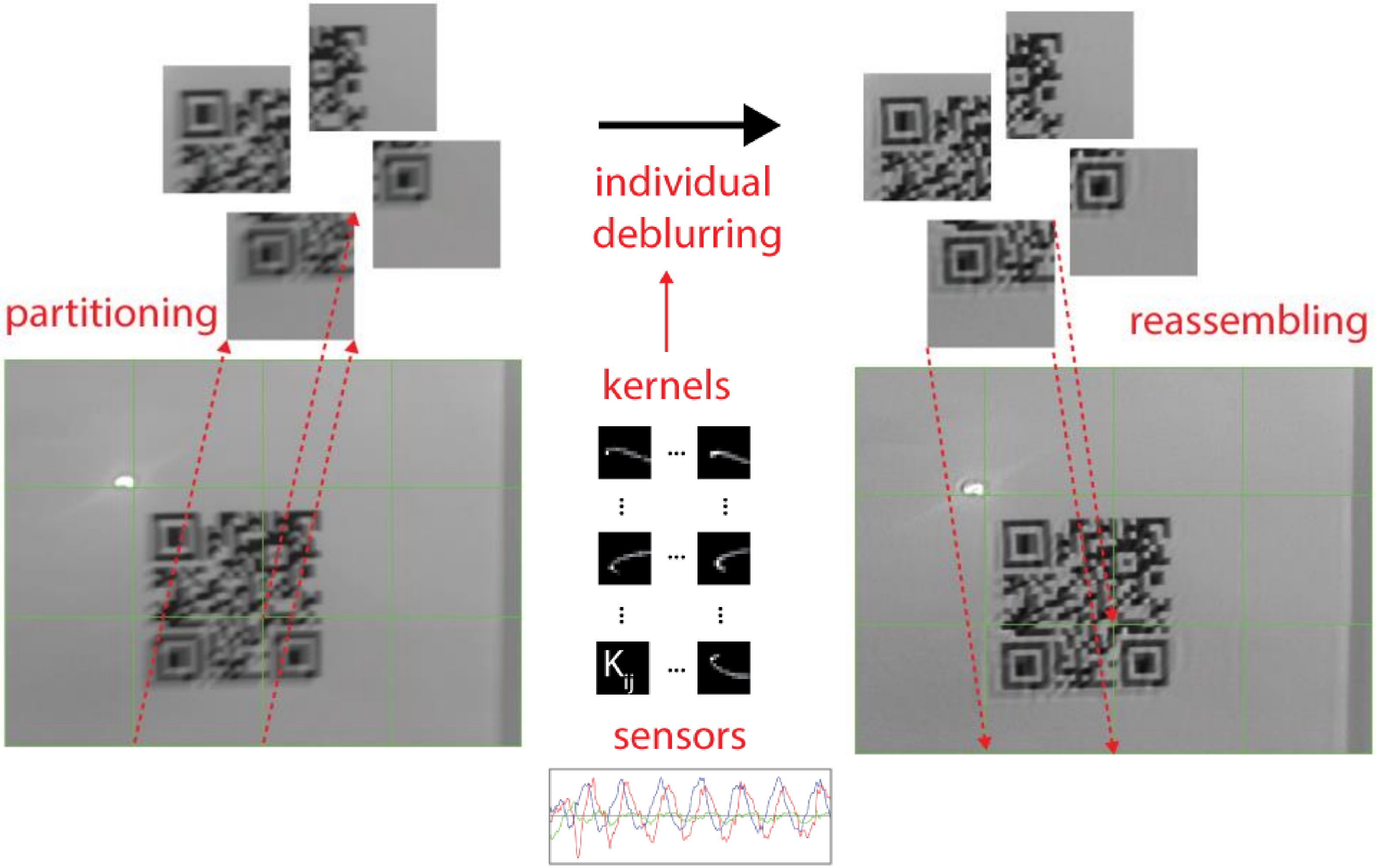
Rendering blur kernels for initialization



Rotational blur depends on the position in the image



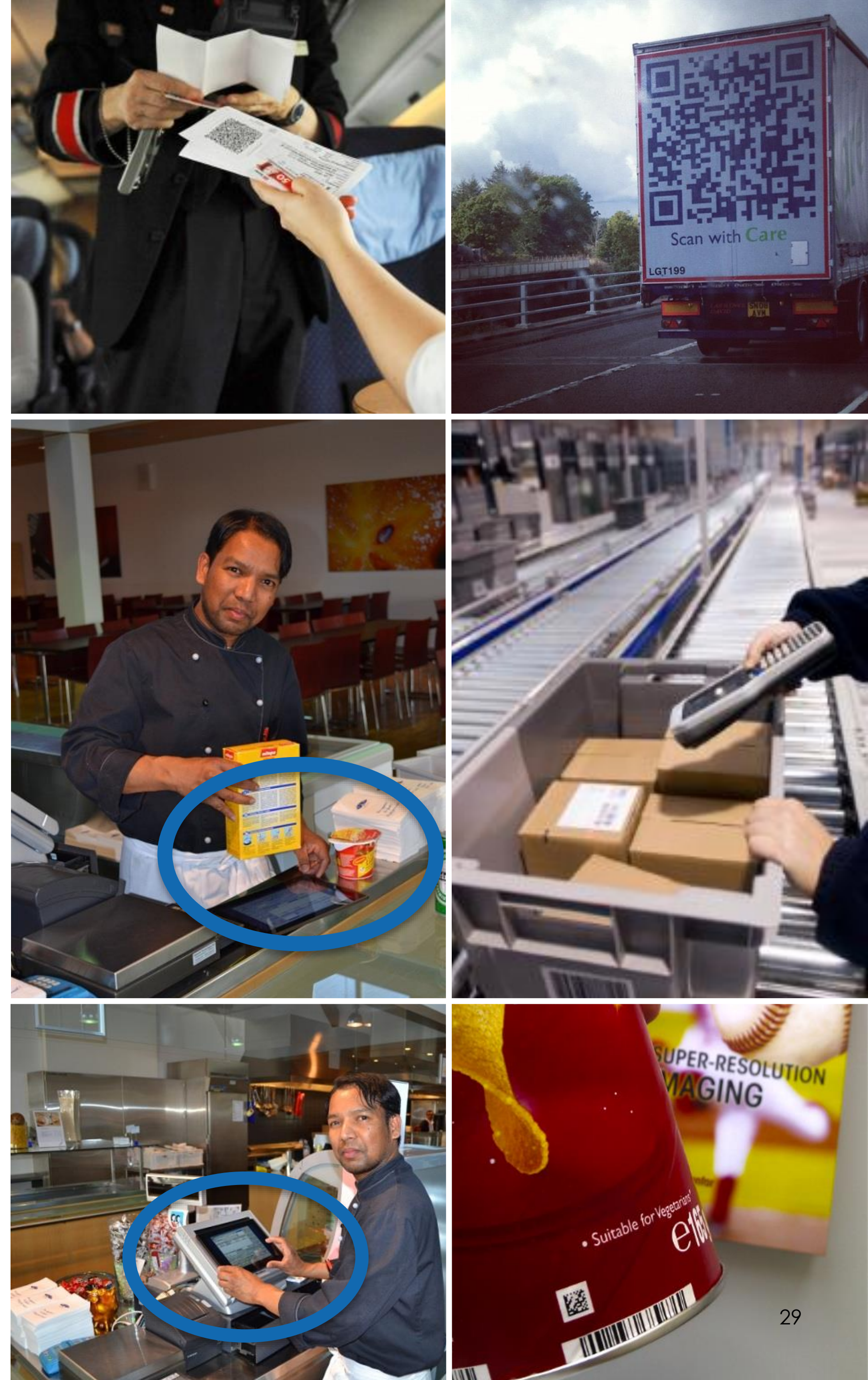
Patch-wise restoration



We can initialize the restoration loop with the rendered kernels

Fast and robust blur removal allows:

- scanning in low lighting
- scanning moving codes
- and tiny or distant codes (super resolution)



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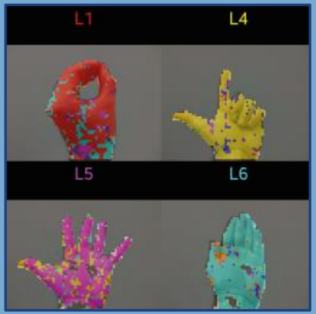


Part III

Codes for interaction with smart objects

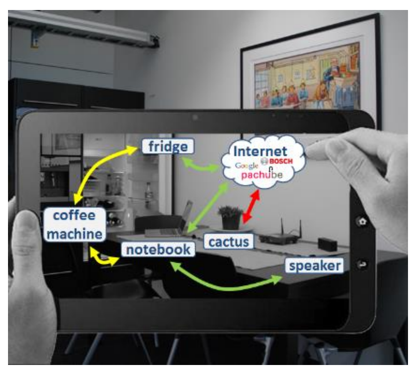
[Rohs 2005]

[Ballagas 2006]

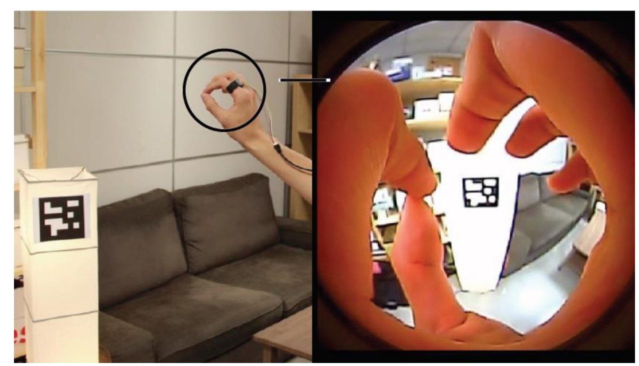
[Mayer 2012]

[Heun 2013b]

[Heun 2013a]



[Mayer 2014]



[Chan 2015]

Outsourcing user interfaces

[Nespresso coffee machine]

[Wahoo cycling sensor]

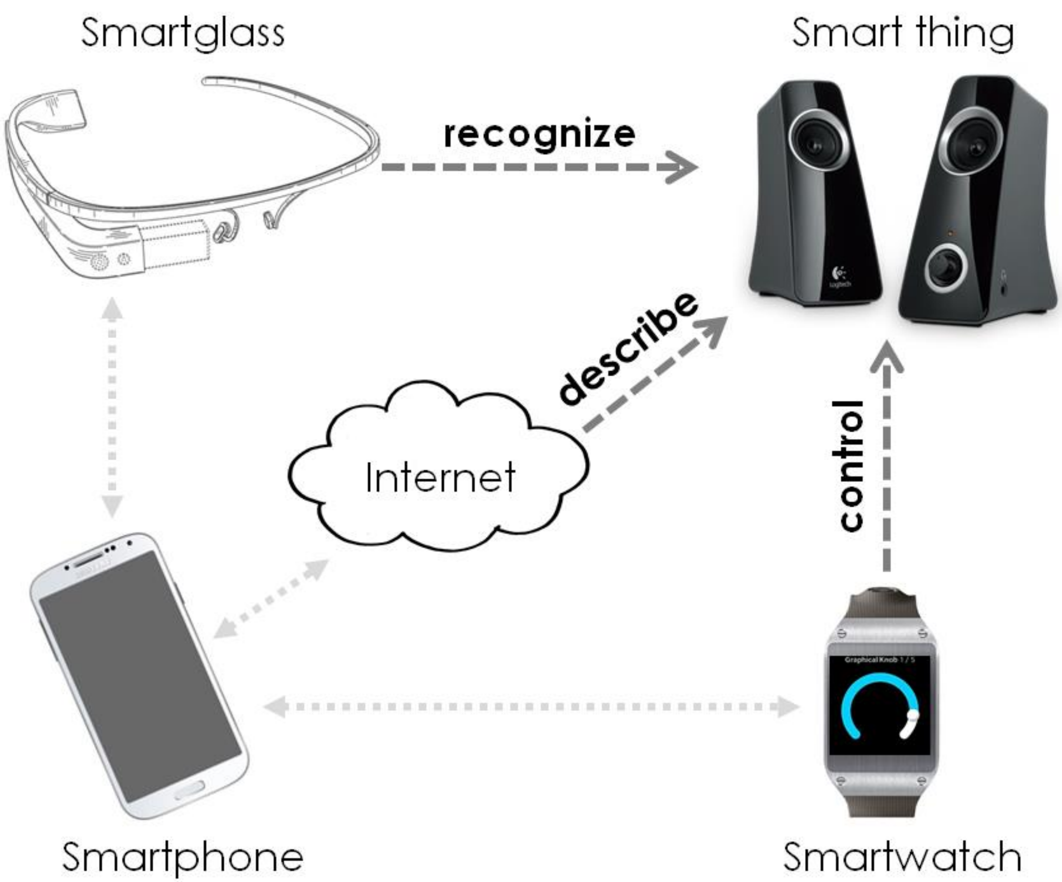
[LIFX light bulb]

[fitbit activity tracker]

The smartphone is becoming a **universal interaction device**.

How about other wearables?

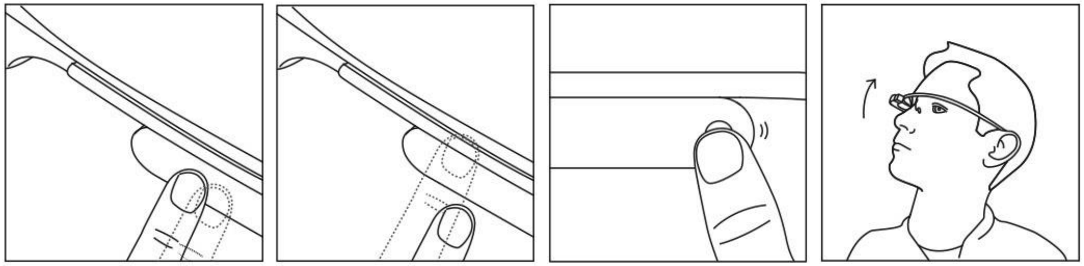
Outsourcing user interfaces



cross-device automatic GUI generation: **user interface beaming**

Joint work with Simon Mayer

Gesture recognition on wearables

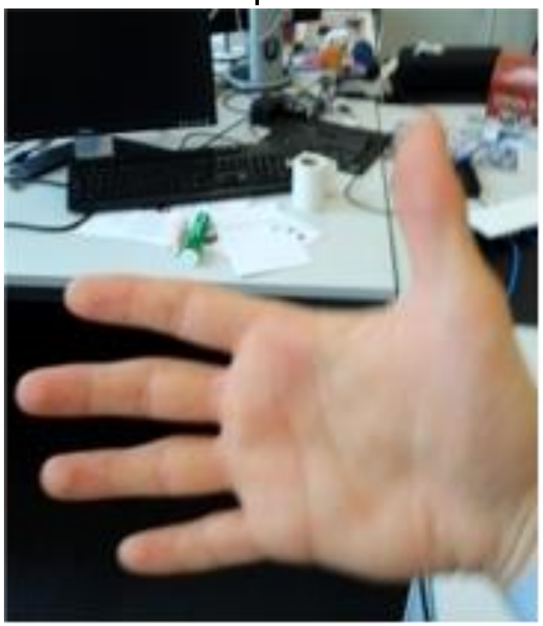


Joint work with Jie Song, Fabrizio Pece, Otmar Hilliges

Live gesture recognition on mobile devices

Gesture classification as pixel labeling

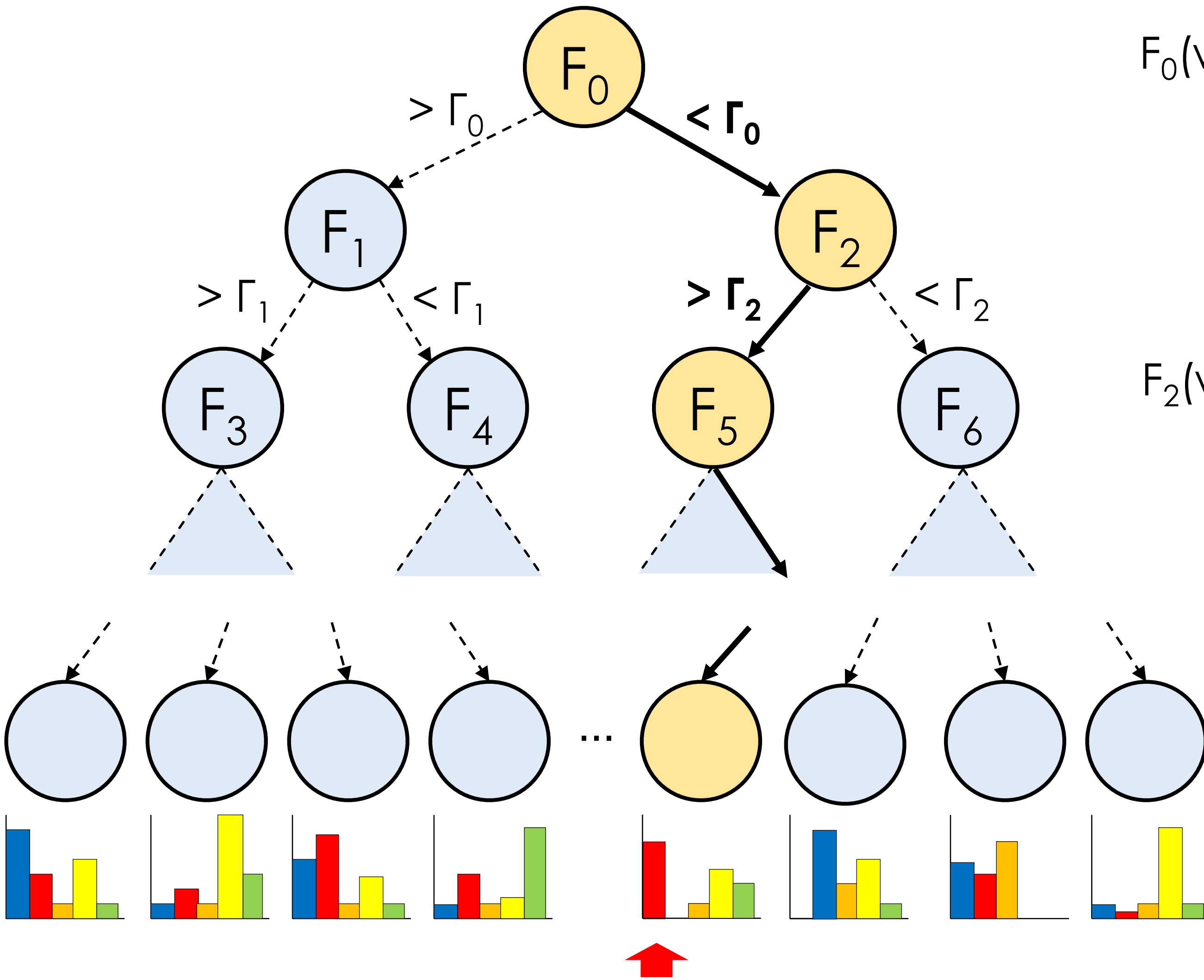
input

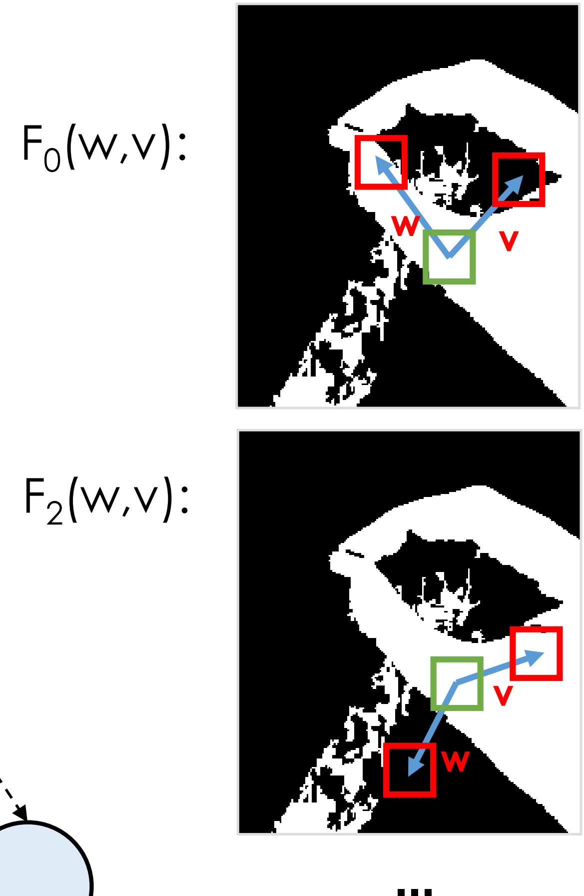


segmentation

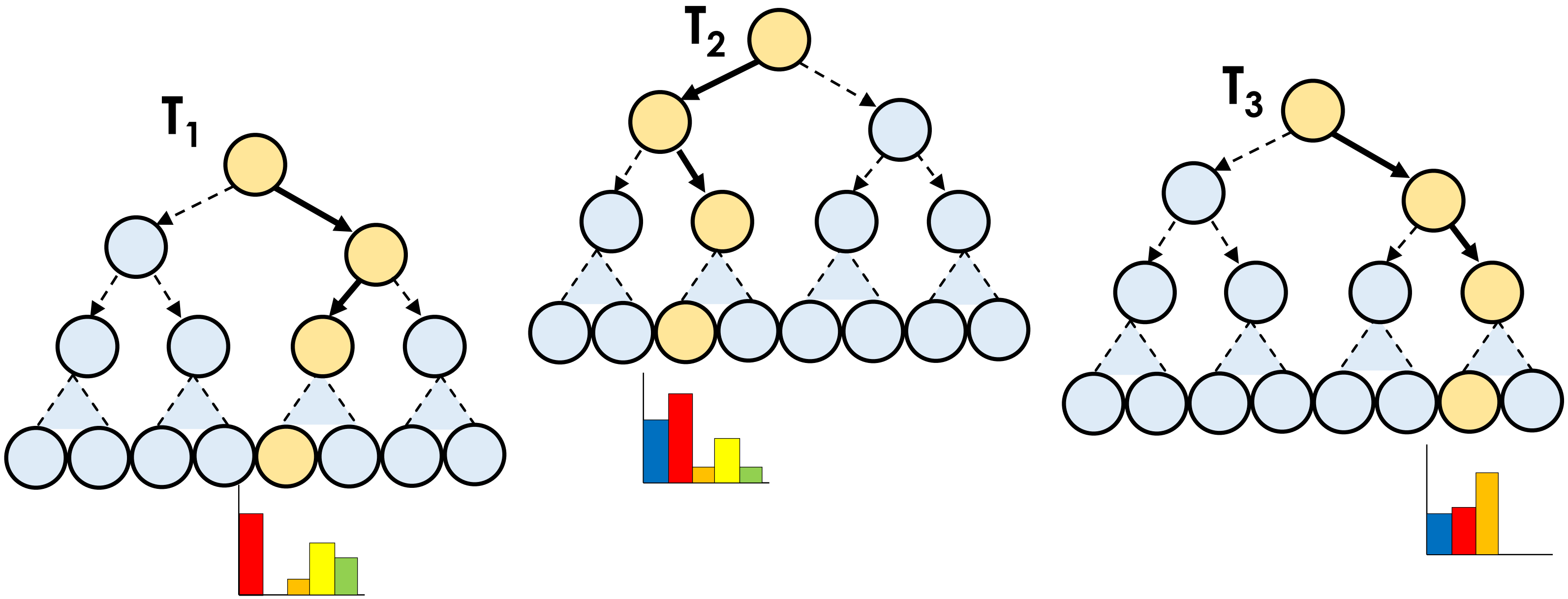
labeled output

Pixel labeling with a decision tree

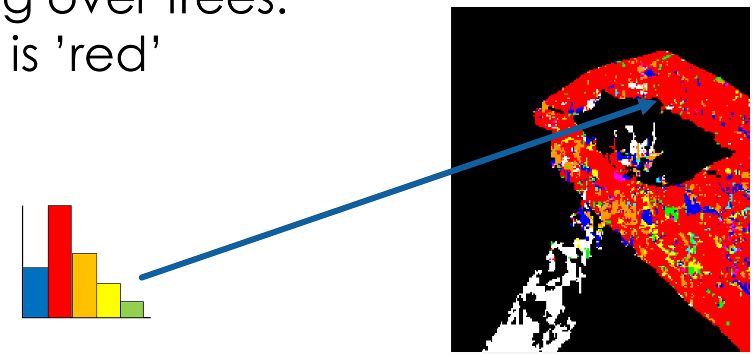




Pixel labeling with a decision forest

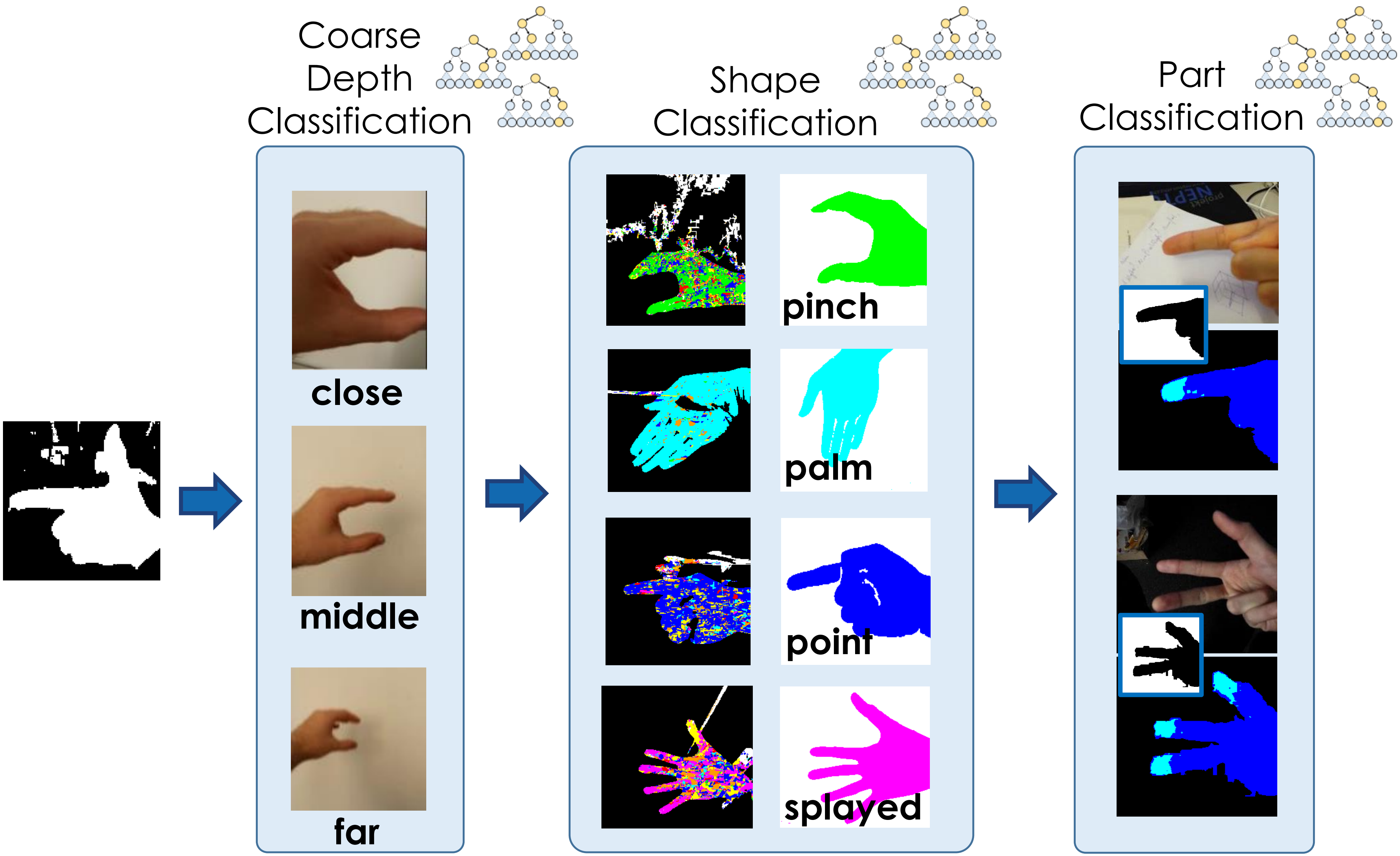


1. pooling over trees:
this pixel is 'red'

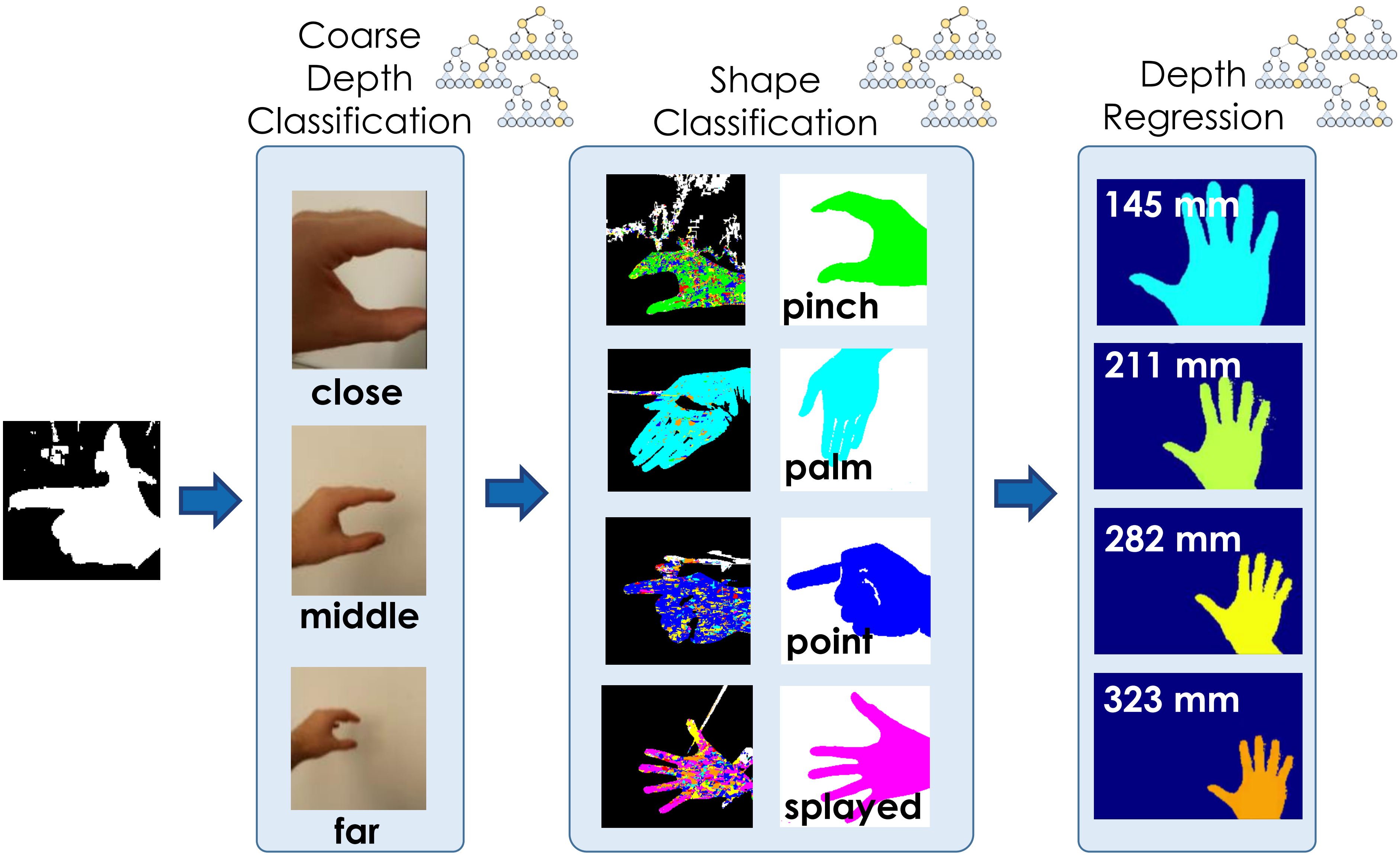


2. pooling over all pixels:
this gesture is 'red'

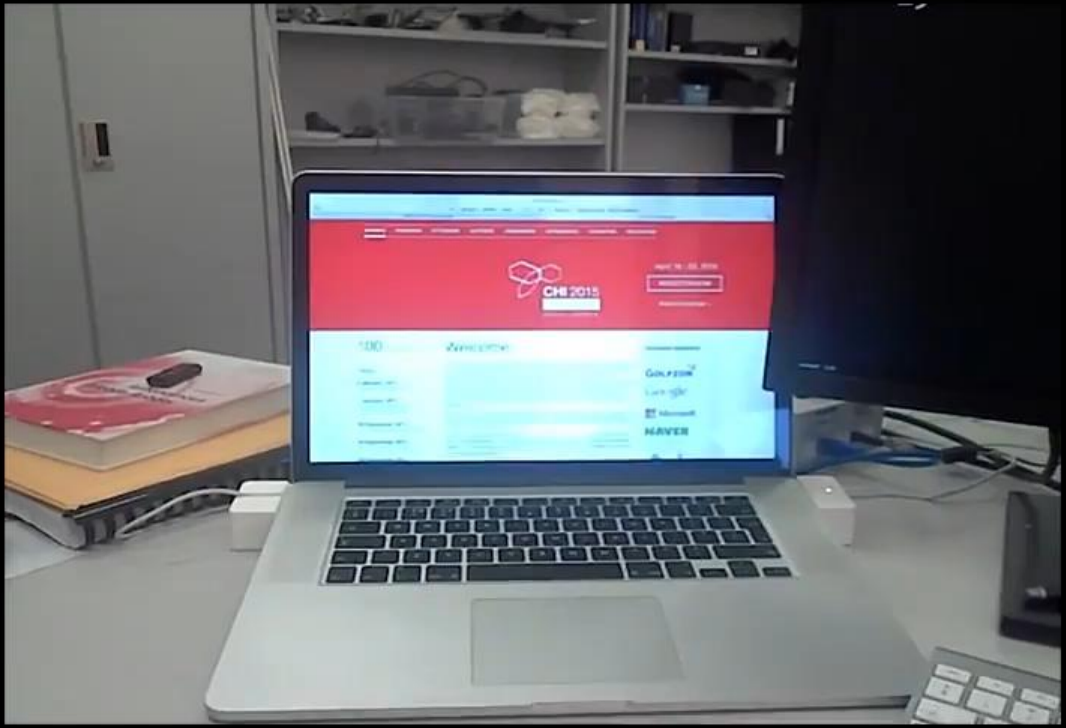
Pixel labeling with multi-stage decision forests

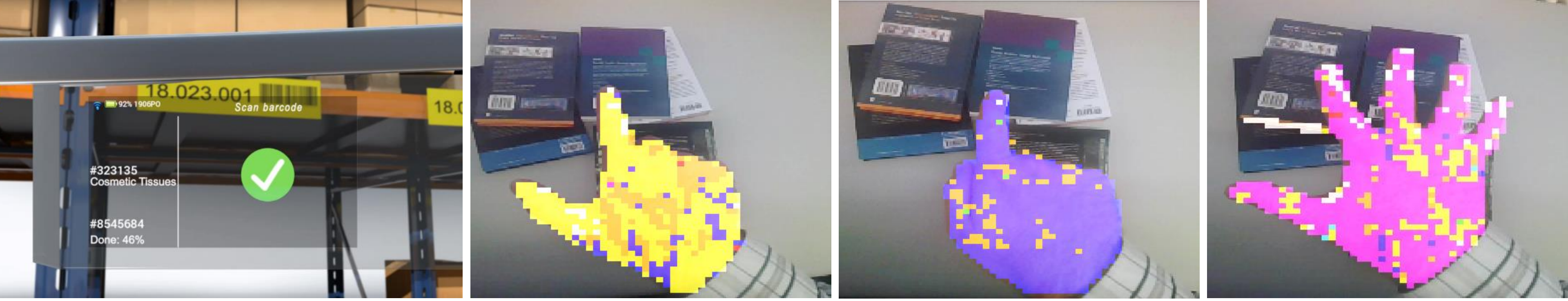


Enabling 3D interaction



Gestures + depth for 3D interaction





Fast and robust gesture recognition allows:

- natural input to wearables
- easy control for scanners
- universal interaction with smart objects (through user interface outsourcing)

Conclusions

In the world of binary images, generally very difficult computer vision problems like …

object segmentation

image restoration

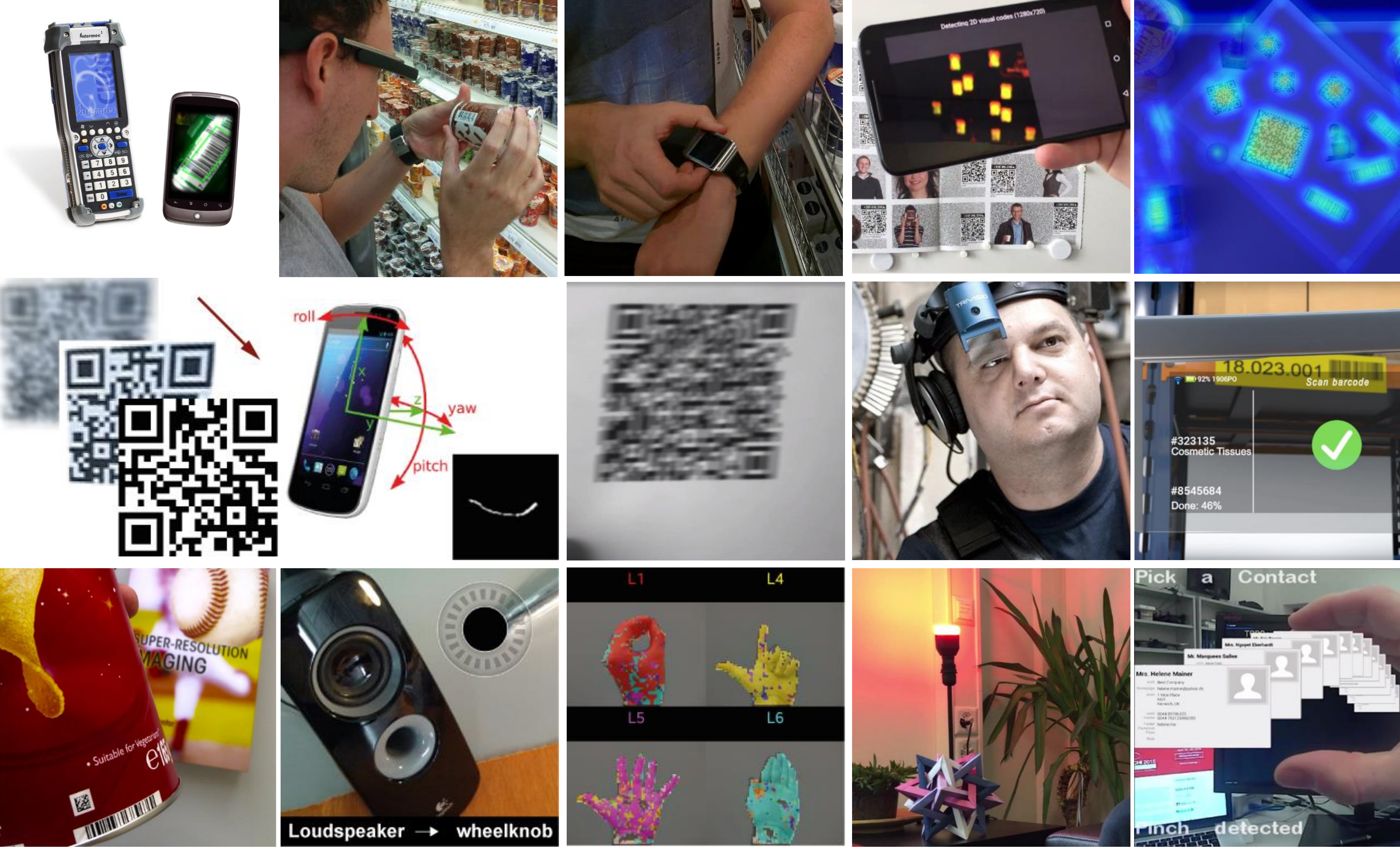
shape classification

… can have **fast** and **robust** solutions even on resource-constrained wearable devices.

Conclusions

Our solutions

- are pushing forward the state of the art in terms of **accuracy**, **robustness**, and **speed**
- can help to make wearable barcode scanning a **promising alternative** to traditional barcode scanning
- will potentially make wearables the essential tools for **bridging** the gap between the **physical** and the **digital** world.


Detecting 2D visual codes (1280x720)
roll
yaw
pitch
18.023.001
Scan barcode
#323135
Cosmetic Tissues
#8545684
Done: 46%
SUPER-RESOLUTION
IMAGING
Suitable for Vegetarians
Loudspeaker → wheelknob
L1
L4
L5
L6
Pick a Contact
Mrs. Helene Mainer
Pinch detected

Thank you!